Two-Stage Gun Projectile Velocity Measurements using PDV

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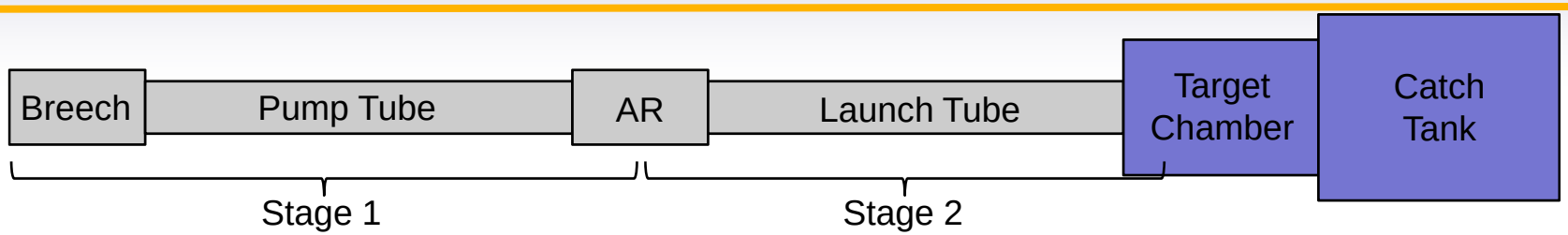
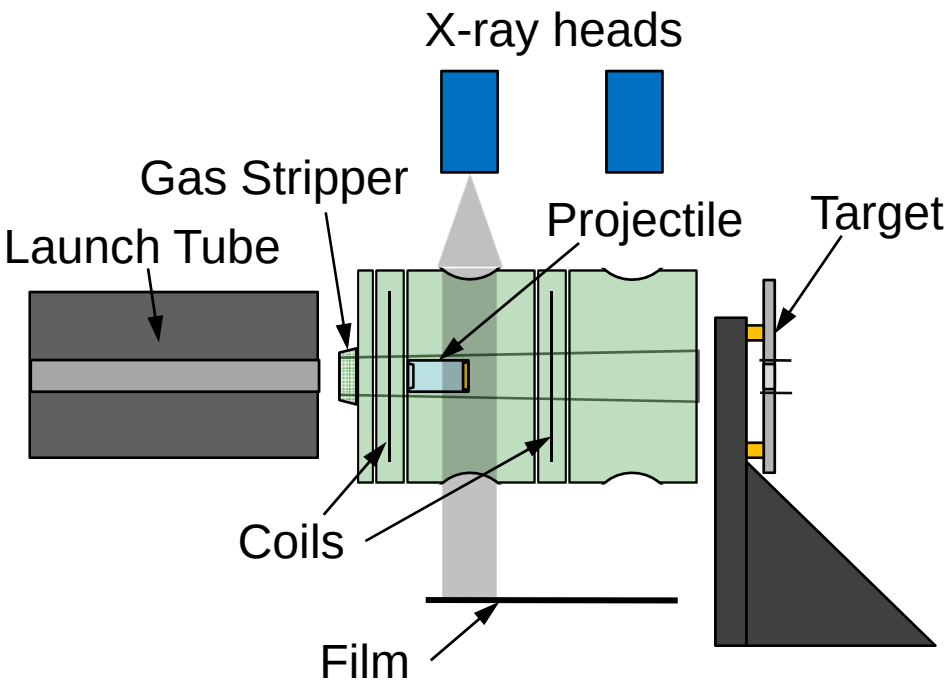
High Performance Two-Stage Light Gas Gun



- Gun designed by General Motors and installed at LANL in 1968 to perform Equation of State (EOS) experiments on metals under high stress, high strain-rate conditions.
- First stage uses up to 8 lbs. of M4-A1 sulfated Howitzer propellant to launch 90mm piston
- Piston compresses H_2 or He gas in pump tube
- Gas pressure builds until diaphragm in Accelerating Reservior (AR) bursts
- Gas is accelerated in AR and launches projectile in Launch Tube up to 8 km/s
- Stresses > 5 Mbar can be reached in EOS experiments on metals

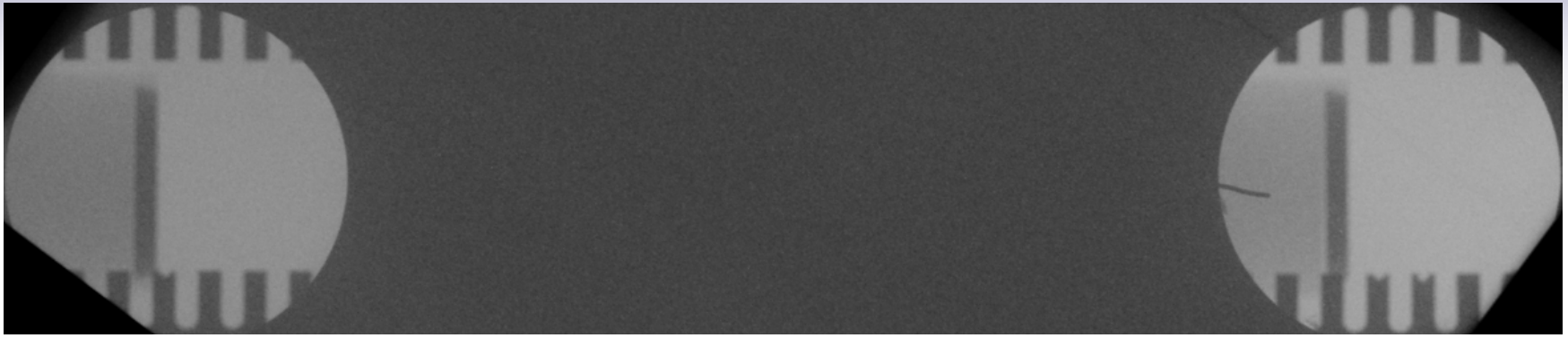
Traditional Projectile Velocity Measurement

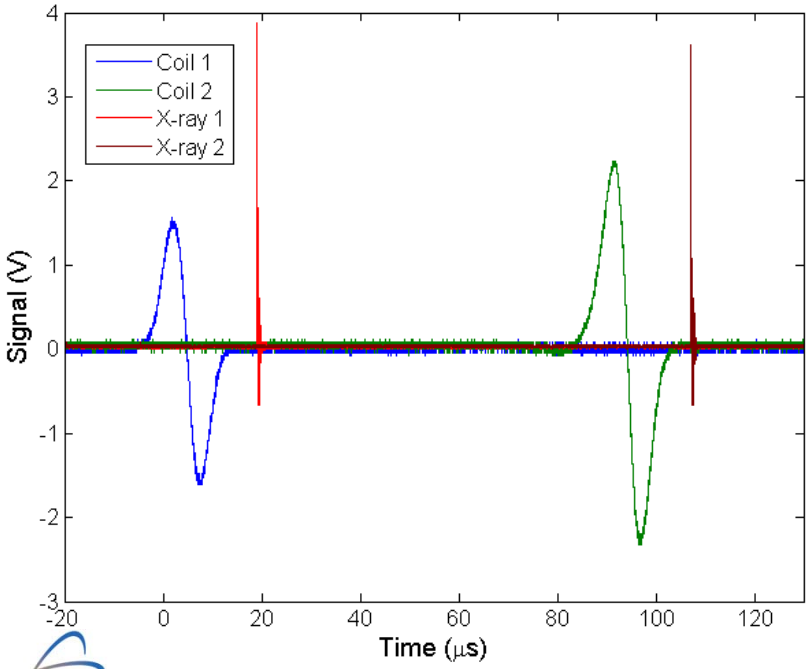
Shorting pins cannot be used at velocities attained in two-stage gun



- Projectile exits launch tube and must pass through gas stripper into coil assembly
- Metal impactor induces current as it passes Coil 1 which triggers X-ray Head 1
- Image of projectile obtained on film or image plate
- Projectile then passes through Coil 2 triggering X-ray Head 2 to obtain second image
- Coil and X-ray pulser signals recorded on digitizer
- Distance between images measured to determine velocity
- Second measurement obtained from coil signals

Typical Results





- Distance measured using 25μm/pixel
- Distance between coils measured before experiment
- Time measured from Digitizer record
- Projectile Velocity calculated
  - Coils: 2.558 ± 0.006 mm/μs
  - X-rays: 2.545 ± 0.010 mm/μs

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Summary of X-ray Measurements

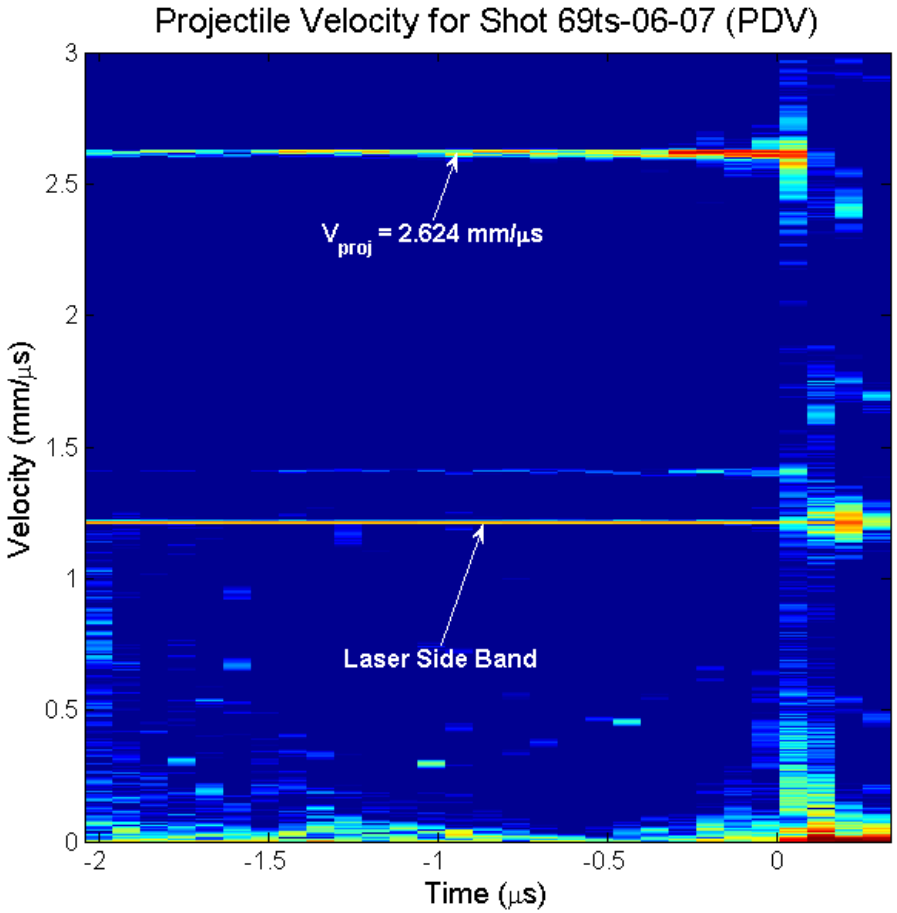
- Advantages
  - Image of impactor obtained before impact
  - Coil signal can provide pre-trigger for experiments
  - Precision of 0.1% can be obtained…
- Disadvantages
  - Difficult to align coil assembly – gas stripper is only slightly larger than projectile
  - Difficult to align target to barrel – must be done before final assembly of gun
  - Difficult to reduce parallax on x-ray film/image plate – both grid and image plate should be in target chamber for best results
  - No image of impactor obtained
  - Prediction of projectile velocity needed to synchronize x-rays with projectile
  - Long free flight distance (20") can lead to large impact tilt at target
    - Tilt values between 17 and 100 mrad obtained during 2006!

PDV as Replacement for Coil/X-ray Measurement

- Coil assembly removed from target chamber
- Target placed 2 in. from end of barrel
- Bare fiber probe placed in target plate to look at edge of impactor as it approaches target.
- Advantages
  - Gun setup is much faster
  - Target alignment is done after gun assembly to better than 0.1 mrad
  - Jensen, *et. al.** demonstrated 0.1% accuracy on free surfaces
  - No free-flight should correspond to lower tilt values
- Disadvantages
  - No long pre-trigger capability
  - High cost
  - No image of projectile

*B. J. Jensen, et. al., J. Appl. Phys, **101**, 13523 (2006)

PDV Comparison to Coil Measurement



- Coil measurement
  - 2.624 ± 0.006 mm/μs
- PDV measurement
  - 2.624 ± 0.003 mm/μs
  - Projectile motion recorded for 40μs.

Projectile Tilt Measurements

With coil assembly

Shot	Velocity (mm/μs)	Tilt (mrad)
69ts-06-01	2.606 (c)	17
69ts-06-02	2.543 (c)	46*
69ts-06-03	2.593 (c)	81
69ts-06-05	2.558 (c) 2.545 (x) 2.555 (v)	45*
69ts-06-06	2.757 (c) 2.748 (x)	36
69ts-06-07	2.624 (c) 2.624 (v)	102

Without coil assembly

Shot	Velocity (mm/μs)	Tilt (mrad)
69ts-07-01	3.513 (v)	9.7
69ts-01-02	3.244 (v)	13.8
69ts-07-04	3.222 (v)	24.2
69ts-07-06	3.228 (v)	12.0
69ts-07-07	3.124 (v)	7.4

(c) Coils (x) X-rays (v) PDV

Dramatic improvement in tilt obtained when coils removed

*Represents best case since only two pins impacted…likely much worse

Conclusions and Future Work

- Traditional projectile velocity measurements on two-stage guns using coils/x-rays have many disadvantages
- Using PDV removed requirement for free-flight distance between launch tube and target
- Accurate projectile velocities obtained – excellent agreement with coil measurements
- Dramatic improvement in impact tilt obtained
- Future: Reduce target to barrel distance to 1” to further reduce tilt